

interests, and to develop a sense of comradeship and co-operation, and this can be done only if we are all made free of the company—if our musical education is such that we can meet each other as frankly and openly in this field as educated men are accustomed to do in the discussion of science or poetry.

AGRICULTURAL ECONOMICS.

The address of Mr. C. S. Orwin to Section M (Agriculture) deals with the importance of the study of agricultural economics. It points out the overriding influence of the economic factor in all matters affecting the management and development of land. Soil, climate, and other factors have their importance, but the farmer can grow anything if there is a market for it, and his main consideration must be in all cases, not what will the land grow, but what can he sell at a profit to himself. Examples are given to illustrate the relatively small importance of soils and climate in crop production and the dominating influence of the market in combination with transport facilities.

Attention is also directed to the need for economic study in the organisation of farm management so as to prevent the wasteful application of one or more of the factors of production: land, capital, and labour. Thus a small farm may be made highly productive by a prodigal use of manual labour, but the same amount of labour applied to a larger area of land in conjunction with a bigger capital outlay on machinery equipment will increase the output per man employed, and it is suggested that production can be directed scientifically and to the general advantage only by a study of the three factors so as to use them in proper relation to each other.

The address aims at directing attention to the fact that the scientific research work in agriculture, which was first inaugurated publicly about twenty-five years ago, has taken no account of the need for the study of agricultural economics, and that agricultural research can never bear its proper fruit until investigations conducted along the lines of natural science are balanced by research work on an equal scale in agricultural economics.

SCIENCE AND CITIZENSHIP.

Sir Richard Gregory's "Message of Science," delivered to the Conference of Delegates of Corre-

sponding Societies, is a plea for closer association between scientific workers and the rest of the community, as a means of promoting social well-being.

Civilised man has proved himself unworthy of the gifts which science has placed at his disposal, with the result that squalid surroundings and squandered life are the characteristics of modern Western civilisation instead of social conditions and ethical ideals superior to those of any other epoch. Responsibility for this does not lie with scientific discoverers, but with statesmen and democracy. Like the gifts of God, those of science can be made either a blessing or a curse, to glorify the human race or to destroy it; and upon civilised man rests the decision as to the course to follow. With science as an ally, and the citadels of ignorance and self as the objective, he can transform the earth; but if he neglects the guidance which knowledge can give, and prefers to accept the phrases of rhetoricians, this world will become a place of dust and ashes.

Unsatisfactory social conditions are not a necessary consequence of the advance of science, but of incapacity to use it rightly. Whatever may be said of captains of industry and princes of commerce, men of science cannot be accused of amassing riches at the expense of labour, or of having neglected to put into force the laws of healthy social life. Power—financial and political—has been in the hands of people who know nothing of science, not even that of man himself, and it is they who should be arraigned at the bar of public justice for their failure to use for the welfare of all the scientific knowledge offered to all. Science should dissociate itself entirely from those who have thus abused its favours, and not permit the public to believe it is the emblem of all that is gross and material and destructive in modern civilisation. It is the pituitary body of the social organism, and without it there can be no healthy growth, mentally or physically.

The Conference of Delegates provides an appropriate platform for this message of exhortation. There are now 130 Corresponding Societies of the Association, with a total membership of about 52,000, and their representatives should every year go back, not only strong with zeal for new knowledge, but also as ministers filled with the sense of duty to inspire others to trust in it.

The Present Position of the Wave Theory of Light.¹

By DR. R. A. HOUSTOUN.

II.

WE come now to the fundamental difficulties. They have been stated very clearly by Dr. G. W. C. Kaye in his book on X-rays, and we shall borrow his method of presenting them:—

(1) When X-rays encounter a gas, only an exceedingly small fraction of its molecules becomes ionised.

(2) The extent of this ionisation is unaffected by temperature.

(3) When X-rays encounter a metal, the corpuscles ejected have a velocity which

(a) does not depend on the intensity of the X-rays, and so is independent of the distance of the metal from the X-ray bulb;

(b) increases continuously with the hardness, i.e. frequency, of the X-rays;

¹ Continued from p. 15.

(c) does not depend on the nature of the metal; and

(d) is equal to the velocity of the cathode rays in the X-ray bulb.

The last fact is a very striking one. To quote from the Robert Boyle lecture recently delivered by Sir William Bragg at Oxford (NATURE, May 19, p. 374):

It is not known how the energy of the electron in the X-ray bulb is transferred by a wave motion to an electron in the photographic plate, or in any other substance on which the X-ray falls. It is as if one dropped a plank into the sea from a height of 100 ft., and found that the spreading ripple was able, after travelling 1000 miles and becoming infinitesimal in comparison with its original amount, to act upon a wooden ship in such a way that a plank of that ship flew out of its place to a height of 100 ft. How does the energy get from the one place to the other?

According to the discussion of these difficulties usually given, the X-rays should spread equally in all directions according to the wave theory. Consequently the few molecules which, according to (1), become ionised should be in some exceptional condition, *i.e.* have a high kinetic energy. But this energy cannot be ordinary heat energy, since according to (2) ionisation does not vary with temperature. It must be some store of internal energy of a radio-active nature, not readily unlocked by outside agencies. The X-ray thus acts as a trigger to start an explosion, of which the corpuscle is the outward and visible sign.

Why should the speed of the corpuscles depend on the wave-length of the X-ray, if the latter merely exerts a trigger action, and why is it independent of the distance of the X-ray bulb? Why is it independent of the nature of the metal? The difficulty of answering these questions in a satisfactory manner has led many to believe that the energy of the X-ray does not spread equally in all directions, but travels in a straight line, and is handed over completely to one corpuscle. Thus we had Bragg's corpuscular or neutral-pair theory of the X-ray and Einstein's quantum theory.

The case for a localised energy theory or entity theory, as it is called, for there are different names, appears at first sight to be strengthened by the numerical values of the quantities involved. The velocity of the cathode-ray particle, the X-ray it produces, and the velocity of the secondary corpuscle are connected by the equation

$$\frac{1}{2}mv^2 = hv,$$

where m is the mass of the cathode-ray particle or secondary corpuscle, v its velocity, h Planck's constant, and ν the frequency of the X-ray. Not only is there agreement between the value of h determined from this equation and the value derived from experiments on black body radiation, but there is extremely good agreement. In an article in the *Journal de Physique* for August, 1920, by M. de Broglie, who has himself added very considerably to our knowledge of both emission and absorption X-ray spectra, there is a description of the methods and a collection of results, from

which it is evident that the differences are less than 1 per cent.

References have been made to Newton's emission theory. It is difficult for students to study this theory, as the "Opticks" has not been printed in English since 1730. A reprint is long overdue; the book is really accessible only in the German, in Ostwald's "Klassiker." There are quite erroneous ideas prevalent about the utility of Newton's emission theory for present-day purposes. Newton himself was not enthusiastic about it, and was cautious about using it. In the first sentence of the "Opticks" Newton says: "My design in this book is not to explain the Properties of Light by Hypotheses, but to propose them and prove them by reason and experiment," and he is very careful in pursuance of this design to make his statements as free from hypotheses as possible. Again and again he uses the word "ray" when it is obvious the thought in his mind is "stream of particles constituting the ray." But he eventually committed himself quite definitely. Light consisted of streams of particles, the violet rays being the smallest particles and the red rays the largest: the glass of the prism attracted the particles in the ray incident on it, and this attraction caused the deviation of the ray: the smaller particles were attracted more strongly than the larger particles, and consequently suffered a greater deviation: hence the formation of the spectrum. In order to explain interference Newton found it necessary to assume that the particles underwent periodic changes of state. These changes he referred to as "fits of easy reflection," because at the changes the particles were reflected more easily; the fits occurred at equal intervals along the path of the ray, and the length of these intervals varied with the colour; for the "rays which paint the colour in the confine of yellow and orange" the interval of the fits was $1/89,000$ part of an inch, *i.e.* 2.8×10^{-5} cm.

But, though Newton adopted the emission theory, he had misgivings on the subject. This is especially evident from a query, No. 13, which he appends to the end of his "Opticks" as a problem suitable for future investigation. This query begins, "Do not several sorts of rays make vibrations of several bignesses, which according to their bignesses excite sensations of several Colours, much after the manner that the vibrations of the Air, according to their several bignesses, excite sensations of several sounds?" Then he suggests that the violet rays make the shorter vibrations, and the red ones the longer vibrations.

Newton's theory is, of course, so hopelessly inadequate for the explanation of interference, diffraction, changes of phase and amplitude, resolving power, etc., that no one has ever seriously thought of applying it to these fields of work. It even gives a wrong value for the pressure of light, a subject in which one would expect it to be at an advantage. The wave theory, on the other hand, holds an extremely strong position in these fields, a position much stronger than is imagined, for few workers at present experiment on such

things as, say, phase difference produced by total reflection, or conical refraction, and consequently there are not many people aware of the extremely high degree of agreement attained. It has not been quite so successful in dealing with the emission and absorption of light; this, however, cannot be ascribed so much to a defect of the theory as to our ignorance of the structure of matter.

Newton's theory being out of the question, and there being no definite alternative offered, we must attempt to explain the phenomena of X-ray energetics on the wave theory. This is not so difficult as is supposed, for in previous discussions important facts have usually been left out.

In the first place the wave theory does not limit us to the harmonic-wave trains of the elementary text-books. It certainly permits of the passage of energy in pulses which widen out very little as they travel. In some signalling experiments a beam of light has been used which was 2 in. wide at one end and 5 ft. wide at the other at a distance of five miles. There would be no difficulty in supposing this repeated on an atomic scale, if we could only imagine a mechanism for getting the beam started. Perhaps electrons vibrating with suitable phase differences on a space lattice might do. In any case it is a matter of arranging the interfering sources suitably; a hint to the properties of the Fourier integral is here enough. White light on the modern view consists of pulses, and we can easily make calculations on the interference, diffraction, and dispersion of such pulses. For example, a single pulse is changed by its passage through a dense flint plate of 1 cm. thickness into a group of about 500 visible waves.

Also it is not necessary that the pulse should be as narrow as the electron in order that all the energy in it should be absorbed by the electron. The analogy of a large metal plate coated with soot is very misleading in this respect. Lord Rayleigh has shown (*Phil. Mag.*, August, 1918), or at least made it plausible, that an electron captures all the energy passing through an area comparable with λ^2/π , where λ is the wave-length.

There is difficulty on the wave theory about starting the energy off along one line, since it would require elaborate and improbable conditions in the source. So it seems preferable to fall back on the other explanation, namely, that of "trigger action."

The spherical wave, uniform throughout its front and diverging from a single point source, is a mathematical fiction, used only in the interests of simplicity. What we have in reality is always a superposition of wavelets from a number of electrons, say n , included within a small region and vibrating simultaneously. These wavelets interfere. If their amplitudes were all the same and equal to a , the resultant intensity would vary from $(na)^2$ to 0, according to the degree of reinforcement present, the lower values being more probable and the average being na^2 . There are thus singular points in the wave-front. The ionisation cannot depend on the intensity of the resultant wave, because this brings us up against the diffi-

culty numbered 3 (a) above. As a result of the interference, though, changes of phase and different rates of change of intensity will be produced, and it is natural to suppose that some complicated combination of these produces the critical conditions; by an accurately timed series of impulses the electron is thrown out of its orbit, and an atomic explosion follows. Thus the objections above headed (1) and (2) are met.

The strongest argument in favour of the "trigger action" theory is undoubtedly the numerical value of Planck's constant itself. There has been comparatively little attention given to the meaning of the quantum itself, or to the connection between the atomicity of energy, or rather action it signifies, and the atomicity of electricity already established. The tendency has been rather to take the quantum for granted and to quantise everything. There has also been a widespread assumption that the quantum is inexplicable in terms of the concepts already existing.

Suppose, however, that we take a sphere of positive electricity of uniform density ρ and radius a , and assume that inside the sphere there is one electron which oscillates about its centre through the positive electricity. Let ν be the frequency of the oscillations, and suppose the radius of the sphere just large enough to neutralise the electron. Then

$$\nu = \sqrt{\left(\frac{\rho e}{3\pi m}\right)} \text{ and } e = \frac{4}{3}\pi a^3 \rho.$$

Now suppose that the electron starts from rest on the surface of the sphere and falls towards the centre. Let v be the velocity acquired by the time it reaches the centre. Then $v = 2\pi a\nu$. On eliminating ρ and a these three relations give

$$v = \left(\frac{2\pi e^2}{m}\right)^{\frac{1}{2}} \nu^{\frac{1}{2}}.$$

If an electron has one quantum kinetic energy, its velocity is given by

$$v = \left(\frac{2h}{m}\right)^{\frac{1}{2}} \nu^{\frac{1}{2}}.$$

The difference between the two formulæ for v amounts to the sixth root of ν , an amount which would scarcely matter if only the visible spectrum were in question, but is much too great when we take the X-ray region also into consideration. But there is a surprising numerical agreement. If we fix our attention on two wave-lengths, (i) that of sodium in the visible spectrum, and (ii) the wave-length 10^{-8} cm. in the X-ray region, we find that the two expressions for v give in the case of (i) 9.29×10^7 cm./sec. and 8.64×10^7 cm./sec., and in the case of (ii) 1.68×10^9 cm./sec. and 6.64×10^9 cm./sec., the second value in each case being given by the quantum formula. Thus there is fair agreement for sodium, but the new formula gives only one-quarter of the correct value in the X-ray region.

The agreement, such as it is, cannot be a chance one. It means that if we construct a model atom in the simplest manner possible, so as to respond

to frequency ν , then the maximum internal energy of the system is of the order of the quantum corresponding to that frequency, and it inspires the hope that some day we may obtain a model which will give an exact agreement. In other words, this calculation gives us good reason for believing that when more is known about the constitution of matter it will be found that a frequency ν is specially qualified for unlocking the quantity of energy $h\nu$.

The difficulty labelled 3 (c) above requires that there should be electrons with a wide range of periods in all metals.

It should be remembered that the phenomena of X-rays themselves, the verification of the theory of scattering, the theory of the crystal lattice, etc., have given us a wide extension of the field of usefulness of the wave theory. It is, of course, nowadays extremely difficult to keep abreast of all the work that is being done even in one field; con-

sequently, different workers attach different values to the facts, and there are many opinions on the points discussed here. But as yet there is no reason for physicists to make any essential change in their attitude towards the wave theory, and in any case it does not conduce to clear thinking to use two mutually contradictory metaphors at the same time.

It is a curious fact that if Euclid does not deserve so much credit for his postulate of parallels as was formerly supposed, he may, on the other hand, lay claim to foreshadowing one feature of some modern views on light. For, according to his "Optics" (*circa* 280 B.C.), he thinks that there are gaps between the rays, that they are localised like the spread-out fingers of a hand; when the observer fails to perceive a small object like a needle lying directly in front of his nose, it is because the needle has got into one of the gaps between the rays.

Classical and Modern Education.¹

By W. BATESON, F.R.S.

FOLLOWING that general misgiving as to our national system of education which, long felt by thoughtful men, found loud and continual expression during the war, Mr. Asquith, then Prime Minister, appointed (1916) Committees to consider the position of natural science and of modern languages respectively. After these Committees had reported, a third Committee was set up (1919) to investigate the position of classics in our educational system. The Report of this Committee, recently issued, is a comprehensive document, full of interesting materials, readable and scholarly, as from the character of the Committee might be expected. The history of classical teaching in the several parts of the United Kingdom, its rise and recent decline, are set out in detail, with an abundance of information never before collected. As to the main inference, no mistake is possible. The classical element in British education is disappearing, and will probably soon be gone altogether.

In the Public Schools few boys are learning Greek, and even Latin, though still generally taught in middle and lower forms, tends more and more to be dropped higher up. None of the new Provided Schools has yet been able to develop a classical tradition and few of them teach Greek. . . . The danger with which we are faced is not that too many pupils will learn Latin and Greek, but that the greater part of the educated men and women of the nation will necessarily grow up in ignorance of the foundations on which European society is built.

The course of events has been exactly that which the defenders of compulsory classics at Oxford and Cambridge foresaw as the conse-

quence of any weakening of front. Classics were maintained in education solely by the authority of the two old universities. Fearing the financial consequences of competition, they reduced the minimum demanded until it became ridiculous, the inevitable result being that Greek had to be dropped, with Latin soon to follow. The reformers were, of course, mostly persons who set no great store by classical education, but they were aided by many representatives of the humanities, who believed, or were persuaded, that the inherent value of classical training was so obvious that it would hold its own without protection. They forgot that, on their abdication, the decision would pass into the control of those who knew the classics only as a symbol of exclusion, with the Board of Education naturally well disposed towards any movement which could be represented as popular.

Probably emanating from that group of the reformers, there are passages in the Report which maintain an undertone of hope. Wonders have been achieved by a few resolute and devoted scholars in some of the most modern universities. This is "of good augury," and "with the enthusiasm born of free choice of subject" there may yet be a revival. Numerous recommendations on points of detail are suggested to this end. The regulations, especially those relating to "Advanced Courses" in secondary schools, and the examination schedules should not be weighted unduly against the classics. In every large district there should be at least one school where Greek teaching can be had and provision is made for boys and girls with literary tastes, and generally the Committee pleads that in every branch of educational administration classical education should be respected as a thing of great worth.

The value of the classics has never been better

¹ "Classics and Education." Report of the Committee appointed by the Prime Minister to inquire into the Position of Classics in the Educational System of the United Kingdom. Pp. 308. (London: H.M. Stationery Office.) 2s. net.